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ISO/CD 15531-32
Industrial automation system and integration — Manufacturing management data exchange : Resources usage management:
Part 32: Conceptual model for resources usage management data

ABSTRACT:
This document provides the conceptual information model for resources usage management data. It gives also some indication on its usage with different type of manufacturing resources.

KEYWORDS:
Resources, manufacturing, data exchange, information model

COMMENTS TO READER:
This document has been reviewed and noted by ISO TC184 /SC4/JWG8 and has been determined to be ready for this ballot cycle.

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Foreword

ISO (the International Organisation for Standardisation) is a world-wide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organisations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardisation.

Draft International Standards (DIS) adopted by technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75% of the member bodies casting a vote.

Attention is drawn to the possibility that some of the element of this part of ISO 15531 may be the subject of patents rights. ISO shall not held the responsible for identifying any or all such patent rights.

International Standard ISO 15531 was prepared by the Technical committee ISO/TC184 *Industrial automation systems and integration*, Sub-Committee 4 *Industrial data.*

ISO 15531-3x series of parts consists of the following:

— Part 31: Resources information model basic principles;

— Part 32: Conceptual model for resources usage management data.

Introduction

Manufacturing resources form the basis and long-term potential of any company. The efficient use of these resources is one of the main goals in industrial management. Comprehensive information about available manufacturing resources is required in order to take the necessary decisions for efficient resource usage. Since many different enterprise functions and therefore also different IT-systems are dealing with manufacturing resources. A common, standardized model for resource description is necessary. That standardised model should enable a company to communicate internally and externally about manufacturing resources and furthermore enable to build up an industrial company's resource database. Its basis will be the definition of an information model for the description of manufacturing resources.

A complete description of manufacturing resources is out of scope of this information model. Only data relevant for decisions concerning the usage of manufacturing resources (e.g. within process planning) will be considered. Therefore only data describing manufacturing resources in terms of their static and dynamic capabilities and capacities to perform manufacturing tasks are within the scope of this information model for resource usage management. There mainly exist two different types of capabilities. On the one hand, there exist capabilities describing a manufacturing resource which are dedicated and unique characteristics in the context of resource management. On the other hand, there exist capabilities which are used within resource management but represent a specific view on characteristics belonging originally to the product description of a manufacturing resource.

EXAMPLE some geometrical or shape properties.

Therefore there is a strong link to the product defining data of manufacturing resources, e.g. described by using the STEP standard.

The data residing in this information model for manufacturing resource management will on the one hand mainly be used within process planning. The results of this planning process, i.e. the assignment of manufacturing resources and the required technological parameters for resource utilisation, will be documented by using means of ISO 10303 STEP. On the other hand the data describing capability and mainly capacity of manufacturing resources will be used together with the process specification as input for scheduling tasks which will be conceptually defined in ISO 15531-4x series.

This document proposes a model of manufacturing resources that is written in EXPRESS and makes extensive an use of the "Integrated Resources" of STEP that are used as far as possible. The model may therefore be used by other SC4 standards as an "complementary resource".

Industrial automation systems and integration – Manufacturing management data exchange –

Part 32: Conceptual information model for resources usage management data

1 Scope

1.1 Scope of ISO 15531-3x series

The parts 3x of ISO 15531 specifies models, and attributes capable of residing in an industrial manufacturing company's resource database which are to be used by manufacturing management for purposes of resource usage management.

The following are within the scope of ISO 15531-3x series:

— the representation of resources information including capacity, monitoring, maintenance constraints and control;

— the exchange and sharing of resource information including storing, transferring, accessing and archiving.

The following are out of the scope of ISO 15531-3x series:

— enterprise modelling such as tools, architectures and methodologies for the modelling of the whole enterprise;

— product data such as representation and exchange of product information;

— component data (parts library) such as representation and exchange of computer-interpretable parts library information;

— cutting tools such as electronic representation for exchange of cutting tool data;

— technical maintenance information such as those included in device repair, operation and maintenance manuals.

1.2 Scope of ISO 15531-32

This part of ISO 15531 specifies the full description of the conceptual model for resources usage management data based on the resource information model and basic principles described in ISO 15531-31.

The following are within the scope of this part 32 of ISO 15531:

— description of the conceptual information model for resources usage management data;

— EXPRESS description of the model and related entities;

— definition of detailed level concepts and entities;

— provision in annex A (informative) of examples of the usage of the model for various kinds of resources.

— provision in annex B (informative) of schema EXPRESS-G layout.

2 Normative references

The following standards contain provisions, which, through reference in this text, constitute provisions of this part of ISO 15531. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties of agreements based on this part of ISO 15531 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

— ISO 10303-1: 1993, *Industrial automation systems and integration - Product data representation and exchange - Part 1: Overview and fundamental principles.*

— ISO 10303-11: 1994, *Industrial automation systems and integration - Product data representation and exchange - Part 11:Description methods: The EXPRESS language reference manual.*

— ISO CD 10303: 1999, *Industrial automation systems and integration - Product data representation and exchange - Part 11:Description methods: The EXPRESS language reference manual.*

— ISO 10303-41e2: 1999, *Industrial automation systems and integration - Product data representation and exchange - Part 41: Integrated resources: Fundamentals of product description and support, 2nd edition version of Part 41.*

— ISO 10303-49: 1997, *Industrial automation systems and integration - Product data representation and exchange - Part 49: Integrated generic resources: Visual presentation.*

— ISO 10303-214:-[1] , *Industrial automation systems and integration - Product data representation and exchange - Part 214: Application Protocol: Core data for automotive design.*

— ISO 10303-224:-[2] *Industrial automation systems and integration - Product data representation and exchange - Part 224: Application Protocol: Mechanical Product definition for process plans using machining features.*

— ISO 13584-1: 1997, *Parts library – Conceptual descriptions - Part 1: Overview and fundamental principles.*

— ISO 13584-42: 1997, *Parts library - Description methodology - Part 42: Methodology for structuring parts families.*

— ISO 15531-1:-[3], *Industrial automation system and integration - Industrial manufacturing management data - Part 1: general overview.*

— ISO 15531-31:-[4], *Industrial automation system and integration - Industrial manufacturing management data - Manufacturing data exchange - Part 31: resources usage management data: Resource information model basic concepts.*

— ISO 8824-1: 1995, *Information technology - Open systems interconnection - Abstract syntax notation one (ASN.1) - Part 1: Specification of basic notation.*

3 Terms, definitions and abbreviations

3.1 Terms defined in ISO 10303-1

This standard makes use of following terms defined in ISO 10303-1:

— application;

— application protocol;

— application resource;

— context;

— component;

— data;

— implementation method;

— information;

[1] To be published
[3] To be published
[4] To be published

— interpretation;

— product;

— product data;

— structure;

— STEP data access interface.

3.2 Terms defined in ISO 10303-41

This standard makes use of following terms defined in ISO 10303-41:

— date_time_schema;

— measure_schema;

— management_resources_schema;

— support_resource_schema.

3.3 Terms defined in ISO 13584-42

This standard makes use of following terms defined in ISO 13584-42:

— property_bsu;

— class_bsu;

— supplier_bsu.

3.4 Terms defined in ISO 15531-1

This standard makes use of following terms defined in ISO 15531-1:

— capability;

— capacity;

— model;

— process;

— resource.

3.5 Terms defined in ISO 15531-31

This standard makes use of following terms defined in ISO 15531-31:

— attribute;

— classification;

— definition of resource characteristic;

— definition of resource view;

— generic resource;

— object;

— property;

— resource characteristic;

— resource configuration;

— resource hierarchy;

— resource information model (RIM);

— resource status;

— resource view;

— structure of resource characteristics.

3.5 Abbreviations

For the purpose of this part of ISO 15531, the following abbreviation applies:

ERP	enterprise resources planning
RIM	resources information model
SDAI	STEP data access interface

Conceptual information model for resources usage management data - schema

3.6 Structure of schema

According to ISO 15531-31 the conceptual information model for resources usage management data is structured into six logical modules (see figure 1). The entity *resource* forms the central element

within the schema. Each further description classifying or detailing a resource's characteristics is related to this resource. The enumeration of these six modules follows a logical order. The ascending order corresponds to the sequences for developing an information model.

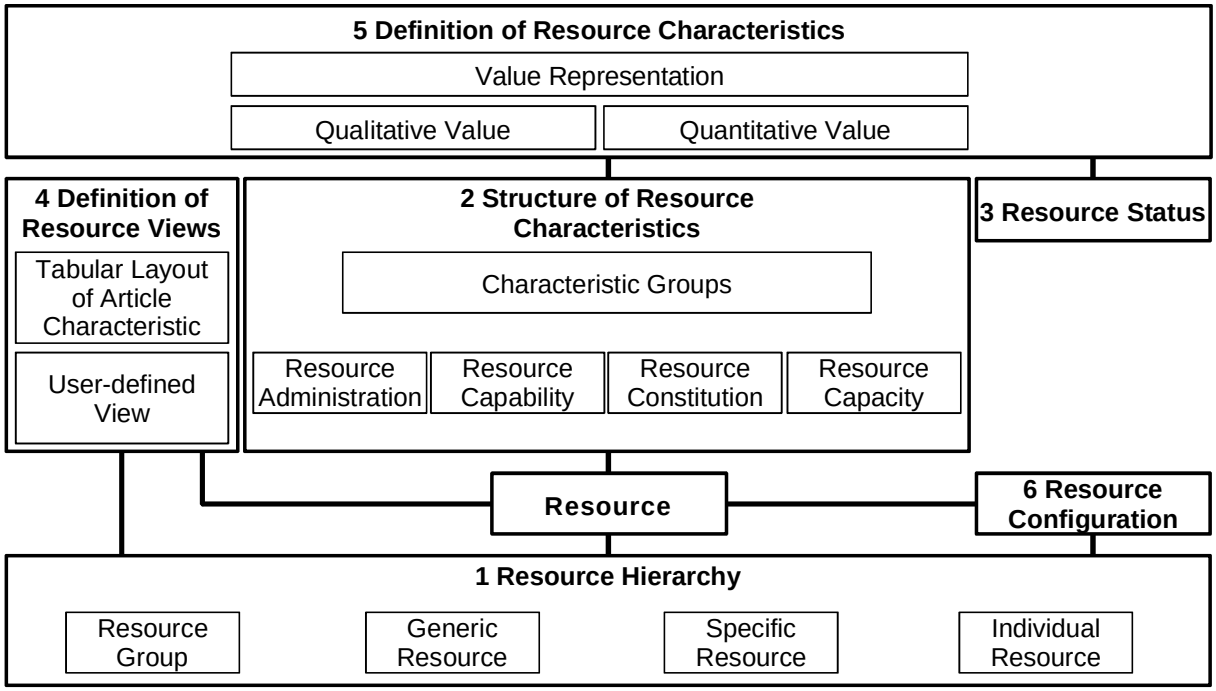


Figure 1: Overview of resource information model

NOTE Examples for the instantiation of the conceptual information model for resources usage management are described in annex A.

3.6.1 Resource hierarchy

A resource hierarchy can be represented by instantiating resource group and generic resource. A specific resource is the specialisation of a generic resource. The individual resource represents physically available manufacturing resources.

NOTE See figure 1 number 1.

3.6.2 Structure of resource characteristic

For resource usage management purposes a resource characteristic comprises information about actual resource status. The attribute classification enables the assignment of a resource characteristic to a resource characteristic group.

A resource administration represents a group of characteristics describing administrative information about manufacturing resources. A resource capability defines a group of characteristics specifying functional aspects of manufacturing resources. A resource constitution represents a group of

characteristics describing the constitution of manufacturing resources. A resource capacity defines a group of characteristics dealing with job related data.

NOTE See figure 1 number 2.

3.6.3 Resource status

A resource status is assigned to each individual resource. A status is defined by a resource status type which provides feedback information on the state of manufacturing resources. A resource status user defined enables the user to define an individual status.

NOTE See figure 1 number 3.

3.6.4 Definition of resource views

A definition of a resource view is derived from a specific aggregation of resource characteristic. A resource view is assigned to a generic resource and can either be represented by a resource tabular layout of article characteristics by a resource user defined view.

NOTE See figure 1 number 4.

3.6.5 Definition of resource characteristics

A resource representation is assigned to a resource qualitative and resource quantitative to represent physical values of a manufacturing resource.

NOTE See figure 1 number 5.

3.6.6 Resource configuration

A resource configuration describes the configuration of a specific manufacturing resource.

NOTE See figure 1 number 6.

The following EXPRESS declaration begins the **resources_usage_management_schema** and identifies the necessary external references.

EXPRESS specification:

```
*)
SCHEMA resources_usage_management_schema;
REFERENCE FROM date_time_schema
   (date);
REFERENCE FROM management_resources_schema
   (person_and_organization);
REFERENCE FROM measure_schema
   (measure_with_unit);
REFERENCE FROM support_resource_schema
   (identifier,
   text);
(*
```

NOTE The schema referred to above can be found in the following parts of ISO 10303-41:
date_time_schema: clause 16;
management_resources_schema: clause 8;
measure_schema: clause 21;
support_resource_schema: clause 20.

```
*)
REFERENCE FROM ISO13584_IEC61360_dictionary_schema
   (property_bsu, class_bsu, supplier_bsu);
(*
```

3.7 Resources usage management type definitions

3.7.1 resource_classification_type

The **resource_classification_type** type is the means by which the value of manufacturing resource characteristics can be classified. This enables the definition of requirements to specific values under the aspects of manufacturing control in comparison to the actual value of a manufacturing resource characteristic.

EXPRESS specification:

```
*)
TYPE resource_classification_type = ENUMERATION OF
   (proposed,
   required,
   realised);
END_TYPE;
(*
```

3.7.2 resource_status_type

The **resource_status_type** type provides a mechanism for the feedback of information about manufacturing resources. Status information of manufacturing resources can be classified under the aspect of processing of feedback information.

EXAMPLE A machine could have a status of requested if expecting a NC data set as information.

EXPRESS specification:

```
*)
TYPE resource_status_type = ENUMERATION OF
   requested,
   registered,
   analysed,
   dispatched,
   noticed);
END_TYPE;
```

```
(*
```

NOTE The results of a model for information feedback is the base for the enumerated classes [7].

requested: currently anticipated requests of process feedback information.

registered: a stored process feedback information that is not yet analysed.

analysed: process feedback information currently prepared to develop measures for process optimisation.

dispatched: process feedback information already given and results expected. Monitoring of launched measures.

noticed: process feedback information respected. Measures for process optimisation realised.

3.8 Resources usage management entity definitions

3.8.1 resource, resource_name, library_resource_assignment and library_property_assignment

3.8.1.1 resource

The **resource** is the basic element for resource management. Each further detailed description, classification or configuration of resources relates to this **resource**.

EXPRESS specification:

```
*)
ENTITY resource
   SUPERTYPE OF (ONEOF ( generic_resource,
   individual_resource,
   resource_group,
   specific_resource) );
   name: resource_name;
   described_by_characteristics: SET OF resource_characteristic;
   holds_view: SET [1:?] OF resource_view;
END_ENTITY;
(*
```

Attribute definitions:

name: the **resource_name** by which the **resource** is known.

described_by_characteristics**:** the set of **resource_characteristics** entities that describes a manufacturing resource.

holds_view: the set of **resource_view**s that are defined for the **resource**.

3.8.1.2 resource_name

A **resource_name** is the identification of a manufacturing resource.

EXPRESS specification:

```
*)
ENTITY resource_name;
   Id: identifier;
   name: text;
END_ENTITY;
(*
```

Attribute definitions:

Id: the identification of the **resource**.

name: the word or group of words by which a **resource** is referred to.

3.8.1.3 library_resource_assignment

A **library_resource_assignment** enables the use of separate resources that are identified by their **resource_name** and are compliant with an external dictionary.

EXPRESS specification:

```
*)
ENTITY library_resource_assignment;
   library_id: ISO13584_IEC61360_dictionary_schema.class_bsu;
   resource_link: resource_name;
END_ENTITY;
(*
```

Attribute definitions:

library_id: identifier for the external dictionary.

resource_link: identifier for the **resource_name**.

3.8.1.4 library_property_assignment

A **library_property_assignment** enables the characterisation of entities and types by an dictionary in compliance with ISO 13584.

EXPRESS specification:

```
*)
ENTITY library_property_assignment;
```

```
   property: property_bsu;
   resource_capability_characterized: resource_capability;
   resource_capacity_characterized: resource_capacity;
   resource_status_type_characterized: resource_status_type;
   resource_classification_type_characterized:
   resource_classification_type;
END_ENTITY;
(*
```

Attribute definitions:

property: the **property** of the object directly or indirectly including the information about the **property_bsu**.

resource_capability_characterized: characterization of **resource_capability** by an ISO 13584-42 compliant dictionary.

resource_capacity_characterized: characterization of **resource_capacity** by an ISO 13584-42 compliant dictionary.

resource_status_type_characterized: characterization of **resource_status_type** by an ISO 13584-42 compliant dictionary.

resource_classification_type_characterized: characterization of **resource_classification_type** by an ISO 13584-42 compliant dictionary.

3.8.2 Resource hierarchy

3.8.2.1 resource_group

A **resource_group** is a type of **resource** that comprises **resource**s to specific groups. These groups are characterized with all elements described by a limited number of identical attributes. The repeated definition of resource groups leads to a hierarchy of manufacturing resources. The **resource_group** as **super_group** contains **generic_resource**s. The **specific_resource**s and **individual_resource**s belong to the same **generic_resource** by the attribute **belongs_to**. To build up a network of resource groups the number of resource levels can be influenced by the instantiation process. Therefore the **generic_resource** has to be chosen accordingly to fit the users constraints or needs in term of level of genericity for reusabilty purpose.

EXAMPLE 1 Resources be structured hierarchically by instantiation of **generic_resource**s in order to differentiate milling machines from drilling machines, turning ones. Then it may be possible to use **specific_resource** and **individual_resource** to go further in the process of concrete representation.

EXAMPLE 2 In order to obtain a representation of a network of resources, the **generic_resource** may be chosen to represent a more generic such of a production centre including milling, turning and drilling machines in order to decrease the number of hierarchy levels.

EXPRESS specification:

```
*)
ENTITY resource_group
   SUBTYPE OF (resource);
   super_group: OPTIONAL SET OF resource_group;
END_ENTITY;
(*
```

Attribute definitions:

super_group: The **resource_group** entity parent of this present **resource_group** entity.

3.8.2.2 generic_resource

A **generic_resource** is a type of **resource** that is characterized by a complete definition of all related attributes without the mandatory link to actual company specific values.

EXPRESS specification:

```
*)
ENTITY generic_resource
   SUBTYPE OF (resource);
   super_group: resource_group;
   described_by: SET [1:?] OF
      resource_tabular_layout_of_article_characteristic;
END_ENTITY;
(*
```

Attribute definitions:

super_group: the upper level **resource_group** into which the **generic_resource** is included.

described_by: the set of **resource_tabular_layout_of_article_characteristic** that specifies article characteristics.

NOTE The generic_resource has no mandatory link to actual values to allow a stepwise instantiation. In the first step a company neutral instantiation with standards and guidelines can be realised. The second step is instantiating individual_resource and specific_resource with company specific values. The fully instantiated and company specific model has the partly instantiated model as its base. This methodology eases the use of the developed information model (compare annex A).

3.8.2.3 specific_resource

The **specific_resource** is a type of **resource** that is a specification of a given **generic_resource**. It will be derived from a **generic_resource** by the linkage of actual values to all attributes other than the attributes for scheduling tasks.

EXPRESS specification:

```
*)
ENTITY specific_resource
   SUBTYPE OF (resource);
   belongs_to: generic_resource;
```

```
END_ENTITY;
(*
```

Attribute definitions:

belongs_to: the **generic_resource** the **specific_resource** is derived from.

3.8.2.4 individual_resource

An **individual_resource** is a type of **resource** that describes physical manufacturing resources of a production system. Their representation enables the relation to dynamic information. The **individual_resource** inherits all attributes and values from the relating **specific_resource**.

EXAMPLE - The **specific_resource** could be a tool set with several similar tools to change them if the wearout increases. All attributes concerning tip types and angles are inherited from the **individual_resource**s.

EXPRESS specification:

```
*)
ENTITY individual_resource
   SUBTYPE OF (resource);
   belongs_to: specific_resource;
END_ENTITY;
(*
```

Attribute definitions:

belongs_to: the **specific_resource** the **individual_resource** is derived from.

3.8.3 Structure of resource characteristics

3.8.3.1 resource_characteristic

A **resource_characteristic** definition includes the information that are needed and defined for resource management purposes.

EXPRESS specification:

```
*)
ENTITY resource_characteristic;
   classification: SET [1:?] OF resource_characteristic_group;
   sequence_of: LIST [1:?] OF resource_representation;
END_ENTITY;
(*
```

Attribute definitions:

classification: the set of **resource_characteristic_groups** to which the **resource_characteristic**s belongs.

sequence_of: the list of the different ordered kinds of **resource_representation** for this **resource_characteristic**.

3.8.3.2 resource_characteristic_group

The **resource_characteristic_group** allows classifications in order to structure the libraries of characteristics.

EXPRESS specification:

```
*)
ENTITY resource_characteristic_group
   SUPERTYPE OF (ONEOF ( resource_administration,
      resource_capability,
      resource_constitution,
      resource_capacity) );
   super_group: OPTIONAL SET  OF resource_characteristic_group;
   name: resource_name;
   described_by: resource_status;
END_ENTITY;
(*
```

Attribute definitions:

super_group: the upper **resource_characteristic_group** to which the **resource_characteristic_group** belongs.

name: the **resource_name** by which the **resource_characteristic_group** is known..

described_by: the **resource_status** by which its status is described .

3.8.3.3 resource_administration

A **resource_administration** is a type of **resource_characteristic_group** that describes administrative information of manufacturing resources.

EXAMPLE Administrative information that are used for the management of resources on an enterprise level are disposition characteristics, actual workload, economic characteristics and production cost. The approval of a resource, especially for human resources is an example for disposition characteristics. A complex machine needs the approval of a permitted person or organization to be used in general.

EXPRESS specification:

```
*)
ENTITY resource_administration
   SUBTYPE OF (resource_characteristic_group);
END_ENTITY;
(*
```

3.8.3.4 resource_capability

A **resource_capability** is a type of **resource_characteristic_group** that describes the functional aspects of manufacturing resources. In particular this comprises the specification of tasks of the activity which a manufacturing resource can execute.

NOTE- A **resource_capability** can be described by its functions, connections, technical characteristics.

EXPRESS specification:

```
*)
ENTITY resource_capability
   SUBTYPE OF (resource_characteristic_group);
END_ENTITY;
(*
```

NOTE Capabilities of a resource that are necessary for the use of the RIM can be represented by reference to the PLib dictionary defined at ISO 13584.

3.8.3.5 resource_constitution

A **resource_constitution** is a type of **resource_characteristic_group** that describes the constitution of manufacturing resources. The description of the constitution comprises information about the actual status of manufacturing resources.

EXAMPLE A **resource_constitution** consists of geometrical, tolerance, material and surface oriented characteristics of resources.

EXPRESS specification:

```
*)
ENTITY resource_constitution
   SUBTYPE OF (resource_characteristic_group);
END_ENTITY;
(*
```

3.8.3.6 resource_capacity

A **resource_capacity** is a type of **resource_characteristic_group** that describes the capacity of manufacturing resources. The description of the capacity comprises information about the potential workload of manufacturing resources.

EXAMPLE The maximum completion time or power available for a given milling machine is its capacity. This maximum completion time, for example, may be limited technically by maintenance, humanly or by law.

EXPRESS specification:

```
*)
ENTITY resource_capacity
   SUBTYPE OF (resource_characteristic_group);
END_ENTITY;
```

```
(*
```

3.8.4 Resource status

3.8.4.1 resource status

A **resource_status** provides feedback information associated with a **resource_characteristic** as an element for the description of the actual status of manufacturing resources.

EXAMPLE Status feedback information can be clustered into proposed, required and realised. Proposed feedback information can differ from the realised characteristic, that refers to a special point of time. Required characteristics are the result of special requirements by a manufacturing task.

EXPRESS specification:

```
*)
ENTITY resource_status;
   belongs_to: individual_resource;
   time_reference: date;
   status_type: resource_status_type;
END_ENTITY;
(*
```

Attribute definitions:

belongs_to: the **individual_resource** to which the **resource_status** is referred to.

time_reference: the **date** to which the **resource_status** is referred to.

status_type: the **resource_status_type** which specifies feedback aspects of information related to the status of resources.

NOTE The use of status is similar to the definition of state in ISO 15531-41.

3.8.5 Definition of resource views

3.8.5.1 resource_view

A **resource_view** is a specific list of **resource_characteristic**s. A **resource_view** is described by an open list in order to enable concurrent use of similar **resource_characteristic**s and generate different views.

EXPRESS specification:

```
*)
ENTITY resource_view
   SUPERTYPE OF (ONEOF ( resource_tabular_layout_of_article_characteristic,
      resource_user_defined_view) );
described_by: LIST [1:?] OF resource_characteristic;
END_ENTITY;
(*
```

Attribute definitions:

described_by: the list of **resource_characteristic**s that is defined as relevant for this **resource_view**.

3.8.5.2 resource_user_defined_view

A **resource_user_defined_view** is a resource_view that is a combination of **resource_ characteristic**s in an application-oriented context.

EXAMPLE The selection of manufacturing resources for a special shop floor area could be an **resource_user_defined_view**. Manufacturing resources could be grouped by their location, products they manufacture and so on.

EXPRESS specification:

```
*)
ENTITY resource_user_defined_view
   SUBTYPE OF (resource_view);
END_ENTITY;
(*
```

3.8.5.3 resource_tabular_layout_of_article_characteristic

A **resource_tabular_layout_of_article_characteristic** is a **resource_view** that is used to combine and select physical and abstract objects with similar characteristics.

EXAMPLE The German standard DIN 4000 is an example for the usefulness of this combination to ease the use of article characteristics [8].

EXPRESS specification:

```
*)
ENTITY resource_tabular_layout_of_article_characteristic
   SUBTYPE OF (resource_view);
   time_reference: OPTIONAL date;
   name: resource_name;
   author: person_and_organization;
   identifying_code: STRING;
   graphics: STRING;
END_ENTITY;
(*
```

Attribute definitions:

time_reference: the **date** by which the **resource_tabular_layout_of_article_characteristic** refers.

name: the **resource_name** that identifies the **resource_tabular_layout_of_article_characteristic**.

author: identifies the author of the **resource_tabular_layout_of_article_characteristic**.

identifying_code: identifier.

graphics: relates to a possible graphical representation.

described_by: the list of the relevant **resource_characteristic**s which define the relevant **resource_characteristic**s.

NOTE The attribute **graphics** represents the name or file name of a graphical representation such as a drawing.

3.8.6 Definition of resource characteristics

3.8.6.1 resource_representation

A Resource_representation defines manufacturing resource characteristics and supports as either the distinction between qualitative and quantitative values.

EXAMPLE A **resource_characteristic** can be quantitative such as the capacity in hours of production time for a milling machine. A qualitative value of a resource could be its ability to be integrated in a production cell including automation.

EXPRESS specification:

```
*)
ENTITY resource_representation
   SUPERTYPE OF (ONEOF ( resource_qualitative,
      resource_quantitative) );
      classification: resource_classification_type;
END_ENTITY;
(*
```

Attribute definitions:

classification: the **resource_classification_type** enumeration is a description of a value of a manufacturing **resource_characteristic**.

3.8.6.2 resource_qualitative

A **resource_qualitative** is a **resource_representation** that describes qualitative values of a **resource_characteristic**.

EXAMPLE A **resource_characteristic** of a manufacturing resource can have qualitative values such as its automation, used palette system or palette identification.

EXPRESS specification:

```
*)
ENTITY resource_qualitative
   SUBTYPE OF (resource_representation);
   optional_descriptions: OPTIONAL SET OF text;
   description: text;
END_ENTITY;
(*
```

Attribute definitions:

optional_descriptions: defines a set of optional qualitative values.

description: text that relates to the nature of a qualitative representation.

NOTE The attribute **optional_descriptions** allows the definition of a set of optional qualitative values to make the qualitative description more concrete. In this context "qualitative" means: not exactly describable or described in quantitative terms.

3.8.6.3 resource_quantitative

A **resource_quantitative** is a **resource_representation** that describes quantitative values of a **resource_characteristic**.

EXAMPLE 1 A **resource_characteristic** of a manufacturing resource can have quantitative values such as the dimensions of the workpieces a resource can manufacture.

EXPRESS specification:

```
*)
ENTITY resource_quantitative
   SUBTYPE OF (resource_representation);
   optional_descriptions: OPTIONAL SET OF measure_with_unit;
   description: measure_with_unit;
END_ENTITY;
(*
```

Attribute definitions:

optional_descriptions: the set of **measure_with_unit** that give optional quantitative values to the **resource_characteristic**.

description: the measure_with_unit that express the physical quantity of a **resource_characteristic**.
NOTE The attribute **optional_descriptions** allows optional descriptions that could be used to represent different measures with unit to ease the models use.

EXAMPLE 2 The maximum temperature for a fluid could be fixed in degree Celsius or in degree Kelvin.

EXAMPLE 3 The weight of a machine can be fixed in metric kilograms or in British pound.

3.8.7 resource_configuration

The **resource_configuration** describes the configuration of resources for a specific manufacturing task. The use of a **resource** by another one can be represented by **resource_configuration** and by the current resource status.

EXAMPLE The resource milling machine includes the combination of several cutting tools as a resource. These cutting tools could be specific for the machine type and limit their use. On the one hand the milling machine is

limited by tools that can be used (size, material). On the other hand the tools as a resource can only be used by a specific machine and were limited in their use.

EXPRESS specification:

```
*)
ENTITY resource_configuration;
   relating_resource: resource;
   related_resource: resource;
END_ENTITY;

END_SCHEMA; -- resources_usage_management_schema;
(*
```

Attribute definitions:

relating_resource: one of the **resources** which is a part of the **configuration**.

related_resource: the other related **resource** which is a part of the **configuration.** If one element of the relationship is dependent upon the other, then this attribute shall be the dependent one.

Annex A
(Informative)
RIM usage cases

A.1 Autonomous production cell

By common understanding autonomous production cells stand for self-reliant production units, which allow long lasting production cycles without any external intervention. These objectives require the capability to react independently to disturbances and modifications during the production process. New ways to allocate planning and control functions are developed within this context. Functions of the autonomous production cell reach from CAD-data-input to delivery of the finished part. Therefore the decentralised cell has to contain a number of specific characteristics, by far exceeding e. g. conventional flexible manufacturing cells [2].

Manufacturing processes are operated in conformance to a parallel run of the corresponding process model that predicts the planned performance. Any difference detected by sensors results in messages to the operator, who is able to introduce the reaction. A disturbance management module proposes measures and evaluates process situations in order to adapt planning bases later. A new user interface is developed, integrating alternative techniques for visualisation. Head-mounted displays with structured representation of necessary information support machine operators receiving and processing data within the shop floor situation. The kernel of an autonomous production cell is formed by a sophisticated machine tool. It is completed by additional machines, that the cell to manufacture working pieces of a nearly complete part family. Hence autonomous production cells represent a bottom-up approach with a company-internal focus.

As described above in autonomous production cells a lot of information has to be transferred among the integrated functions of the unit. Intermediate results of planning have to be stored in order to provide necessary information for each step of order processing. For order specific information management a feature-based product data model was developed and invented [3]. Resource information, which is order-neutral, is the other decisive part of data management in autonomous production cells. For each planning step a suitable set of information is required. Size and kind of cutting edges are e. g. important data for NC-planning. A machine tool list with information about the capabilities of the machine (processes, size, power, feed-rates etc.) is required to choose the manufacturing equipment during the planning process. The availability of current data about machine tool condition, e. g. present tool magazine load, is crucial. Although all of these objects (cutting edge, tool, machine tool) are resources, their totality contains more information than the single resource. The cutting edge belongs to certain tools, which can only be used in certain machine tools. This hierarchic structure has to be represented in a resource information model. Obviously a number of resource classes can be defined. Each one is described by a certain set of parameters, which is also valid for lower classes of the resource hierarchy. All machines have an inventory ID, an hourly rate or an axes specification. Each milling machine is described by additional parameters like tool cone size or zero offset. A resource information model should be able to maintain different resource types and sub-types together with its sets and sub-sets of parameters.

All requirements mentioned so far must result in a resource information model. A suitable modelling language represents the basis for model design. The third step is implementing the model in a database.

The main requirements concerning the resource information model are the representation of a resource hierarchy and the representation of links between resources. Furthermore inconsistencies and redundancy must be avoided. These requirements are best met by an object oriented modelling method. In addition, in order to reflect the mentioned criteria of platform neutral location, independent multiple data access has to be ensured. Therefore a standard modelling method resulting in a standardised model is necessary.
In order to apply the Resource Information Model it has to be instantiated in two steps. In a pre-instantiation the model has to be adapted to a content. Therefore norms and specific guidelines have to be implemented to the generic model to refine it for a specific structure. This pre-instantiation is independent from a specific use and guarantees a compatibility between the different uses. Pre-instantiation results in a description of a specific resource, e. g. a special type of milling machine. Next step is the instantiation of a physically existing resource, the individual resource. Individual resources represent the actually available resources with all relevant description data like load status etc.

Using the standard model for representing resource information is an elementary condition for the exchange of this data between different users.

This standardised resource information model has been implemented on a database and was instantiated for various tools and tool machines. Database implementation in principal is possible with relational and object oriented databases. Due to the fact that the logical structure of EXPRESS is strongly related to object oriented representation, the object-oriented database ONTOS was chosen for implementation. Main disadvantage of relational databases in this case is the need of representing relations between objects with additional data. This increases data volume and danger of inconsistency in database structure. By using object oriented database all advantages of object oriented modelling are present.

The developed and implemented resource information model has to be made accessible for users of autonomous production cells and for Virtual Enterprises. Pure database access and additional functions, e. g. for capacity planning, based on resource information are necessary.

Since the resource information model implemented on a database is a prerequisite for information management in decentralised production structures, only network-based solutions for electronic communication are taken into consideration. Possible approaches are to be found in the field of tele-co-operation, where recently lots of solutions have been developed.

The chosen OO-database, which contains the resource information, is linked with a Common Gateway Interface (CGI) to a Web server providing the Internet access. User interfaces are designed with Hypertext Mark-up Language (HTML). This architecture allows bi-directional access to the database. The user interface can be modified easily, e. g. for different user profiles in Virtual Enterprises or autonomous production cells.

Any request of a user to the database is sent by the browser using the HTTP format. The server then passes the control to an engine, e. g. a CGI-bin process, dealing with the request by possibly querying the database using SQL via ODBC-standard. The query is then processed by the database system returning the result.

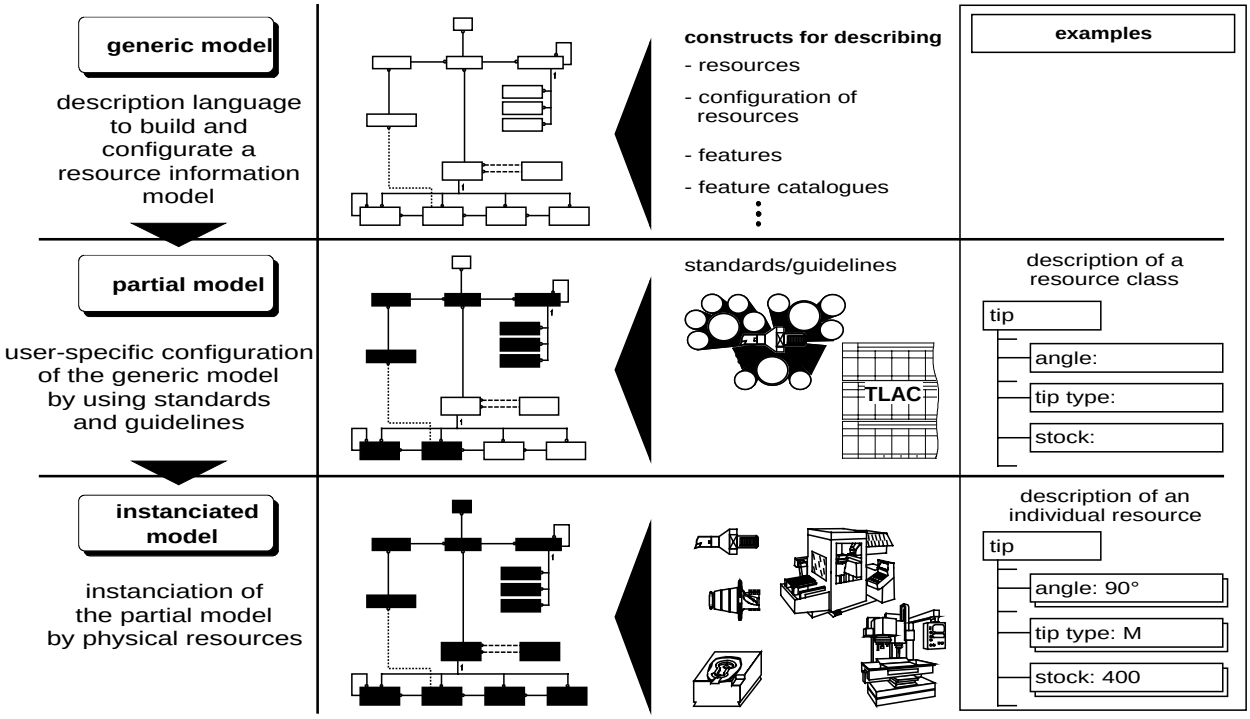
The site was designated to work on the Internet at the same time as being part of an Intranet. In order to achieve this goal, certain security features had to be developed. The first security level is made by the Web server itself, which is built on the operation system level. Access control can be realised by restricting the permitted IP addresses, requiring assigned user accounts and passwords. The user rights can be limited in the operation system, assigning permissions to folders and files on the server. In addition to the operation system security features the Web server can also be set not to accept anonymous requests. It is able to support the Secure Sockets Layer (SSL) protocol, now securely encrypting data exchange between server and clients.

The above described interface is designed for pure database access. New resources can be registered, data structures of the database can be modified, e. g. in order to implement an additional machine tool type.

A.2 Cutting tools

Representing a resource hierarchy and defining a resource view form the first instantiation level of the generic model. A partial model has to be derived in order to configure the model regarding to user-specific demands (see figure 2) [1]. It is generated by instantiating **resource_group** and **generic_resource**, including the definition of a **resource_view**. The actual instantiation of the model with physical resource data is based on the partial model. Physical values of manufacturing resource characteristics are represented by **resource_representation** which can either be qualitative or quantitative.

A **resource_status** is assigned to each **individual_resource**. A status is defined by a **resource_status_type** which provides feedback information on the state of manufacturing resources. Moreover a **resource_status** has a **time_reference** to date which is represented in the **date_time_schema** of ISO 10303-41e2.



Key: TLAC - Tabular Layout of Article Characteristic

Figure A.1: Instantiation levels of the conceptual information model

A.3 Human resources

Despite increasing mechanisation of work in industry and business [6], people are still associated with, and are essential to most operating systems. Certainly the worker's role is changing, the worker being relieved of many routine and/or hazardous tasks. This trend will continue, but there will always be a need for people, and the emphasis will therefore move to the design and management of worker-machine systems.

Let us consider the situation in which worker and machine are interdependent, in which neither can work effectively or continually without the other. When a worker uses a machine, a loop or closed system results. The worker will receive certain information from the machine, either from dials, displays, etc., designed for that purpose, or by observations of the machine itself. He or she will process this information and make decisions on what action, if any, to take and may then manipulate controls or attend to the machine in some other way so as to affect its behaviour in the desired manner.

A work system, whether manual, automated or a combination of both, is established to fulfil certain job requirements. Certain tasks or activities must be performed. One requirement in the design of the system, therefore, is the allocation of these tasks to the active parts of the system, i.e. their division between man and machine. This allocation of functions must reflect the abilities of man and machine, that is their skills, capabilities and limitations.

In the context of manufacturing management systems, since both of them, men and machines, are essential for the manufacturing process of a product, their function, or their role, has be considered,

therefore depicted by the term of “resources”. As such, the functions assumed by either man, or machine, will have to be considered and allocated through a three steps analysis:

— step 1: job or task analysis: to determine jobs/tasks which must be undertaken by the work system;

— step 2: skill analysis: to identify the skills/abilities of the component parts of the work system, i.e. the worker(s) and the machines;

— step 3: allocation of tasks: to allocate tasks from step 1 to the component parts of the system as far as possible to match step 2.

All these functions can be found in the current Resource Information Model.

The applicability of the Resource Information Model to human resources will be shown here on the test case of a manufacturing company whose production is organised in three product lines (three types of screws), or “Channels”, called Scr1-C, Scr2-C and Scr3-C.

Each channel is responsible for its own production, from raw materials to despatch.

The number of people involved in the three production lines are:

—channel 1: 20 (support) + 80 (production);

— channel 2: 10 (support) + 30 (production);

— channel3: 6 (support) + 20 (production).

Each channel is in turn subdivided into several sub-channels, corresponding to:

— administration of the production line;

— standard products (screws and nuts, stock);

— customer order products (small or big quantities, quick production).

Each sub-channel can be described according to the same organisational structure, in two axes (machine tools and tooling, personnel), represented on the following schema:

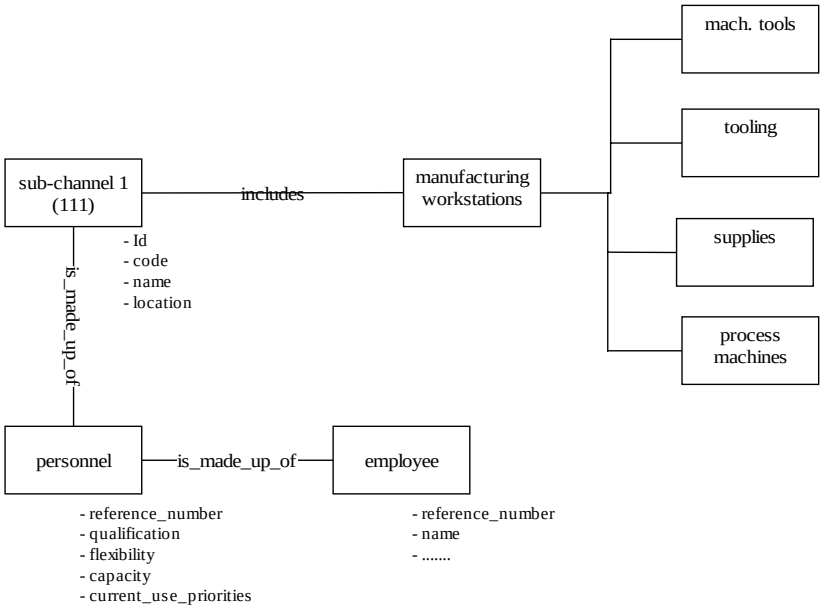


Figure A.2: Schema of RIM implementation for human resources

Definition of the attributes of the schema:

Id: reference of the channel;

code: code of the channel;

name: name of the channel;

location: physical location of the channel in the workshop (layout);

reference_number: personal id of the employee;

qualification: recognized skills of the person;

flexibility: possibility to vary the time schedule (work in shifts), possibility of over time etc.;

capacity: normal working schedule: full time, half time, holidays, illness, etc.;

current_use_priorities: already described priorities and/or hierarchy of higher priorities;

reference_number: personal id of the employee;

name: name of the employee.

People traditionally belong to a channel, however, when necessary and according to their skill (represented by the entity **resource_qualitative**), workers can be allocated to another production line. People working for the same channel belong to a **resource_group**.

The name of the worker is defined by a **resource_name**. **Individual_resource** will be used to describe the worker by the role, the function he assumes within the channel.

Resource_status describes his current state in the production system.

Features of the personnel of the channel are defined through **resource_characteristic**, then classified into **resource_characteristic_group**, super-type of the following entities:

— **resource_administration**: for the general administration of company's people, through the channel they work for;

— **resource_capability**: for **human** beings, this primarily concerns skills and competencies possessed, responsibilities which can be assumed and authorities which can be exercised by them;

— **resource_capacity**: providing the normal working schedule (full time, half time, holidays, illness, etc.).

Generally speaking, a **resource_characteristic** collects all the information related to the people involved in the work system, describing their qualification, flexibility, capacity and current use priority. A powerful use of this entity, when applied to workers, offers the possibility to deal with the concept of "resource potential": within a production system, it is important to be able to know if there is a possibility of additional capacity for a resource, for example the extraordinary use of a person for an extraordinary task. This potential is expressed in terms of resources, and defines a reserved capacity that can be allocated on demand. Of course, this human resource potential relies on the skill of the worker, his capacities and the *current use priorities* of the manufacturing company.
Once this potentiality identified for a resource, its effective translation into the work system can be made by the entity **resource_configuration**, describing the configuration of the resource for a specific manufacturing task.

External references through the use of PLib services enable the extension of the **resource_status_type** type, notably to offer additional possibilities within the SELECT clause, such as, for human resources: the availability, the level of priority of current use, the next free capacity time, the efficiency (e.g. to take into account temporarily unavailable people).
It will be the same case for the **resource_classification_type** type, where the use of PLib services will enable the extension of the SELECT clause to other classes, such as: the list of qualifications, the list of capacities, the list of possible flexibility (various time schedules to be provided for the personnel).

This case study based on the description of the production line of a manufacturing company, from the point of view of the staff involved in the manufacturing process, provides a good example of the possibility of use of the Resources Information Model for representing human resources.

A.4 Software and Data set

The RIM is generic enough to be applied to any software or data set resources usage management data as well. Any needed specialisation may be obtained by reference to the ISO13584/IEC61360 dictionary schema included in the model.

First of all, a resource hierarchy can be defined using one or more **resource_groups** associated to one or more **generic_resources**. That shall include the definition of a **resource_view.** Then a **specific_resource** is a specialisation of a **generic_resource**, used to specify a given class of software or data set, while the **individual_resource** represents physically available software or data set.

The **resource_configuration** is used to characterise, from a the point of view of a software or for data set usage management, the configuration of the software or data set (the parameters needed for its management). Physical value of software or data set characteristic are represented by **resource_representation**.

The features of the software or the data set are defined through one or more **resource_characteristics** and then classified into a **resource_characteristic_group.**
A **resource_characteristic_group** may be one of the followings:

— a **resource_administration:** for general administration purpose like usage rights, key validity etc.

— a **resource_capability and resource_capacity:** by the reference to the ISO 13584 data dictionary schema, allows to describe any needed capability or capacity feature for the management of the software or data set during the manufacturing process**.**

— a **resource_constitution** may be used to represent information about the actual physical characteristics of software or data set such as their size or language etc.

Generally speaking, **resource_characteristic** collects all the information related to the software and data set involved in the manufacturing process and especially all the information needed to manage their usage: capability, capacity, administration characteristic, size, languages, associated software and data set, starting and ending conditions, etc.

In addition a **resource_status** is assigned to each **individual_resource** through a **resource_status_type** which provides feedback information on the state of software or data set during the manufacturing process and ensures the liaison with the manufacturing process flow management. A **resource_status** has a **time_reference** to a date which is represented in the **date_time_schema** of ISO 10303-41e2 or with a **point_in_time** of ISO 15531-42.

This quick and rough implementation "guideline" or usage case of the RIM for software and data set shows its very large capabilities to manage the usage of this type of resources during the manufacturing process as well as the other resources described in the previous clauses of this annex.

Annex B
(informative)

EXPRESS-G diagram

The diagram in this annex corresponds to the EXPRESS schema specified in this part of ISO 15531. This diagram uses the EXPRESS-G graphical notation for the EXPRESS language. EXPRESS-G is defined in annex D of ISO 10303-11.

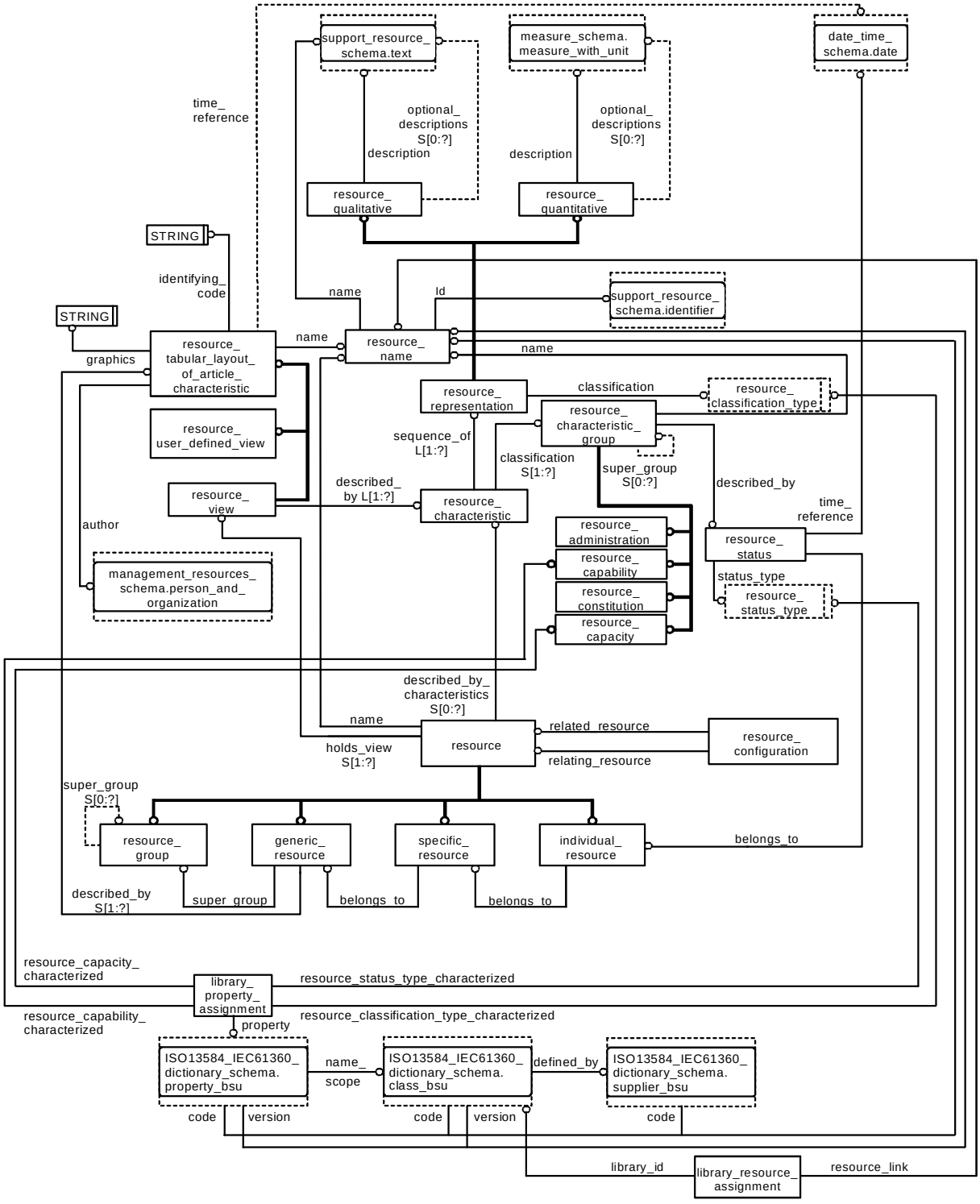


Figure B.1: Resources_usage_management schema – EXPRESS-G diagram

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